

## **Optical Constituents Along a River Mouth and Inlet: Variability and Signature in Remotely Sensed Reflectance**

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Grant Number: N00014-12-1-0109  
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### **LONG-TERM GOALS**

The goal of our research is to improve our ability to assess and predict the distribution of water column optical properties in the coastal region.

### **OBJECTIVES**

Our research in the New River Tidal Inlet had three primary objectives:

1. Measure the variability of optical properties in-space along a river mouth/inlet and observe the variability in time at a single position over a tidal cycle;
2. Relate this variability to the concentration and dynamics of dissolved and particulate materials, including variability in the particle size distribution;
3. Relate the optical properties to the ocean reflectance, so algorithms to invert surface color to in-water constituents can be tested and improved.

### **APPROACH**

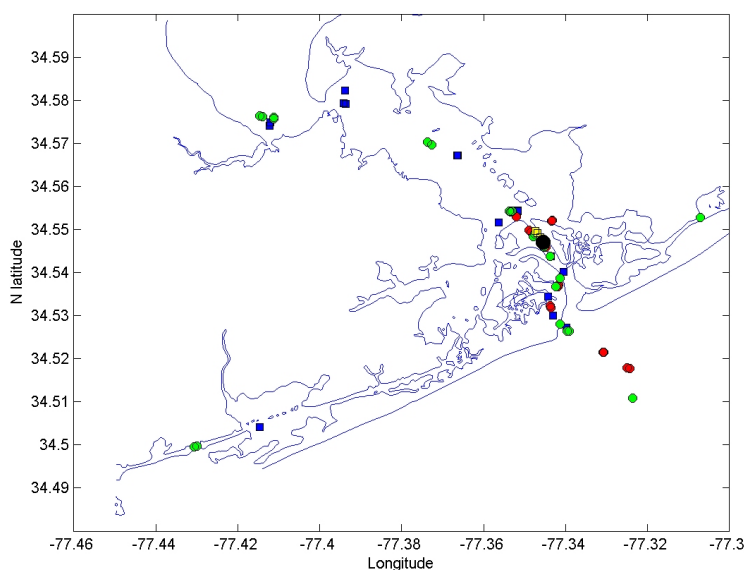
Our work on in situ optical and particle properties was coordinated with the work being carried out on physical processes and remote sensing in the New River, North Carolina during the RIVET project. Our sampling effort consisted of deploying 2 instrument packages to measure particle size and optical properties at a series of stations located along the New River and through the mouth. The first package used to profile water column particle size distributions consisted of a LISST 100x Type C, Digital Floc Camera (DFC), and RBR CTD. The second comprised a WETLabs ac-s, BB-9, a CDOM fluorometer

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE <b>30 SEP 2013</b>		2. REPORT TYPE		3. DATES COVERED <b>00-00-2013 to 00-00-2013</b>	
4. TITLE AND SUBTITLE <b>Optical Constituents Along a River Mouth and Inlet: Variability and Signature in Remotely Sensed Reflectance</b>				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) <b>Dalhousie University, Department of Oceanography, Halifax, Nova Scotia, Canada B3H 4J1,</b>				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT <b>Approved for public release; distribution unlimited</b>					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT <b>Same as Report (SAR)</b>	18. NUMBER OF PAGES <b>6</b>	19a. NAME OF RESPONSIBLE PERSON
a. REPORT <b>unclassified</b>	b. ABSTRACT <b>unclassified</b>	c. THIS PAGE <b>unclassified</b>			

and a Seabird CTD (IOP package) and was used to determine backscattering and absorption coefficients of particulate and dissolved substances. A third drifting package was deployed to measure hyperspectral upwelling radiance and downwelling irradiance. Water samples were collected and filtered for analysis of particulate mass and organic carbon. Finally, a size settling velocity camera was deployed on the bottom over a tidal cycle.

## WORK COMPLETED

We conducted 5 days of sampling of which the last three days with the IOP package at the New River Inlet using the two profiling packages. Measurements were done as follows: In days 1 and 2 samples were collected at different locations along the river. In day 3 we anchored the R/V and performed profiles ~once every half an hour at one location. In day 4 we followed a dye patch as it was advected with the tide. Finally in day 5 we sampled out at sea and in the Inlet to characterize the end members of the inlet (see Fig. 1 for station locations).



**Figure 1. Site map for sampling effort in New River Inlet, North Carolina. Different colors and symbols represent different sampling days.**

The data collected were processed using standard protocols, including the assignment of uncertainties. Full particle size distributions were determined using data from the LISST and DFC following the protocols developed in the OASIS project (Hill et al., 2011). Mass normalized backscattering and absorption of particles, crucial inputs into ocean-color inversion models in the coastal ocean, e.g. Nechad et al., (2010), were derived.

Radiative transfer modeling using Hydrolight was used to test for closure between radiometric measurements and in-situ optical properties (e.g. Mobley et al., 2002) and the degree of disagreement contrasted with the uncertainties in measurements (e.g. Wang et al., 2003).

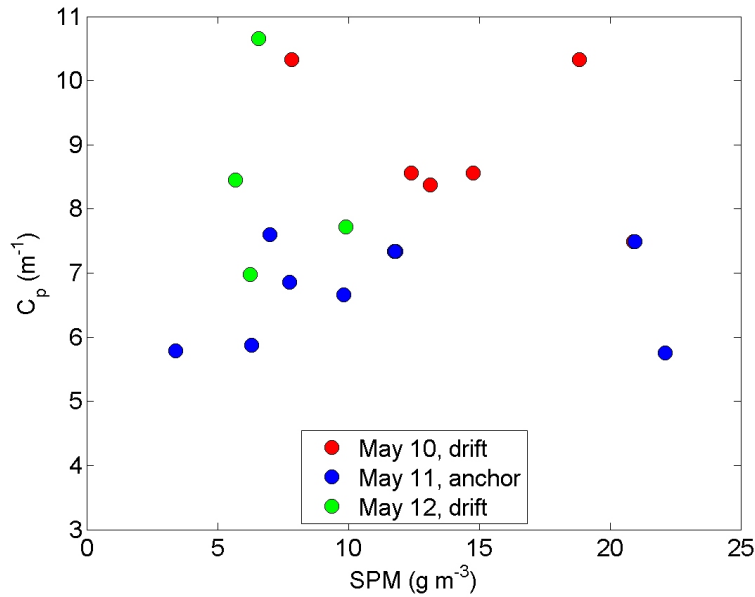
## RESULTS

Analysis has focused on the relationship of the beam attenuation coefficient to suspended sediment mass. The ratio of beam attenuation coefficient to suspended particulate mass ( $c_p:SPM$ ) is affected by particle size and density, both of which can change rapidly in inlets. Changes in  $c_p:SPM$  degrade the accuracy of estimates of suspended mass that are based on beam attenuation, as well as degrading predictions of remotely sensed properties based on models of suspended particulate mass.

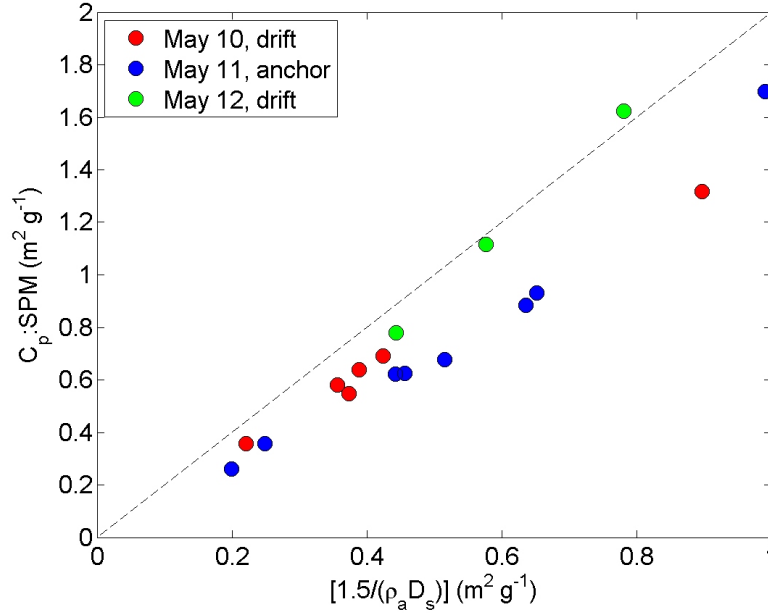
Three basic results have emerged:

- $c_p:SPM$  varies in New River Inlet, confounding the relationship between optical, particle, and remotely sensed properties.
- $c_p:SPM$  is predictable with conventional methods that require manual measurements.
- Optical measurements can constrain the variability in  $Cp:SPM$ , leading to better automated estimates of  $SPM$ .

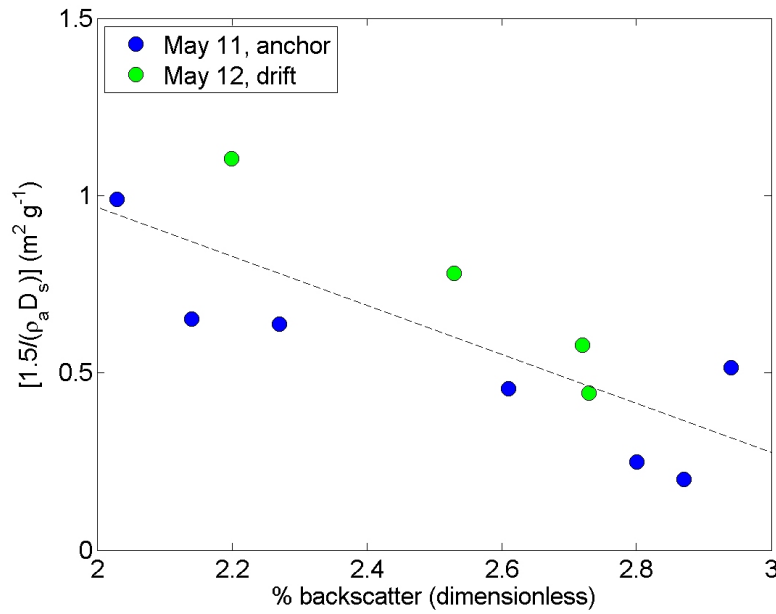
No significant linear relationship between  $c_p$  and  $SPM$  existed in New River Inlet during the measurement period (Figure 2). Lack of linear relationship indicates that variations in particle size and density degraded the correlation between  $c_p$  and  $SPM$ . Theoretically,  $c_p:SPM$  varies as  $(1.5/\rho_a D_s)$ , where the apparent density,  $\rho_a$ , is the dry mass over wet volume and  $D_s$  is the Sauter diameter of the suspension. This correlation does exist in New River Inlet (Figure 3), but it requires water samples to estimate dry mass over wet volume. Previous work has shown that apparent density affects backscatter ratio in suspension, offering a possible way to constrain  $(1.5/\rho_a D_s)$  remotely and, as a result, improve estimates of  $c_p:SPM$ . The quantity  $(1.5/\rho_a D_s)$  is related to backscatter ratio New River Inlet (Figure 4). Estimates of mass made by correcting the attenuation coefficient by a factor determined by the backscatter ratio vary linearly with measured  $SPM$  (Figure 5).



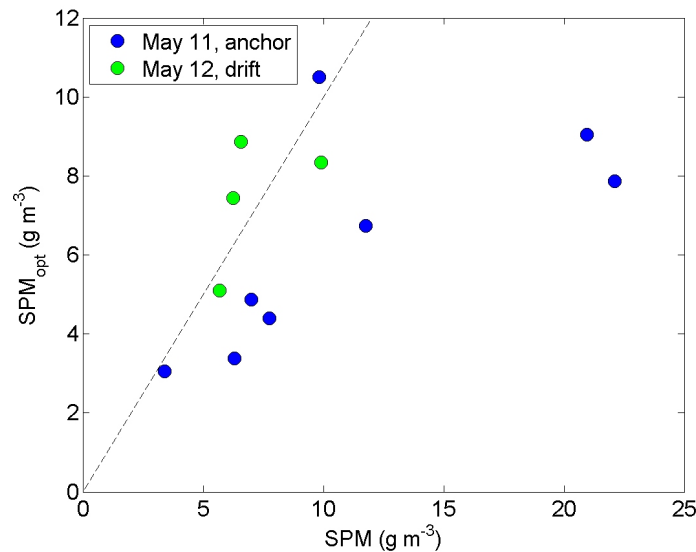
**Figure 2. Beam attenuation ( $c_p$ ) versus suspended particulate mass ( $SPM$ ). Different colours indicate different sampling days. The lack of linear correlation indicates that particle size and/or particle density vary in New River Inlet.**



**Figure 3.** The ratio of beam attenuation to suspended particulate mass ( $c_p:SPM$ ) versus the area to mass ratio ( $1.5/\rho_a D_s$ ). Correlation is linear and near the 1:1 line shown in gray. The apparent density is estimated from water samples, which can be limiting during long-term or remote instrument deployments designed to monitor suspended sediment concentration.



**Figure 4.** Suspended particle area-to-mass ratio ( $1.5/\rho_a D_s$ ) versus the backscatter ratio in suspension. Inverse linear correlation exists because backscatter ratio is affected by particle composition, which affects apparent density. The linear correlation can be used to correct optical estimates of mass based on the beam attenuation coefficient.



**Figure 5. Suspended particulate mass estimated with  $c_p$  and the backscatter ratio versus measured suspended particulate mass. The clustering of points around the grey, dashed 1:1 line shows that optical estimates of mass can be accurate even in dynamic inlets.**

## RELATED WORK

The in-situ measurements of particle size, beam attenuation ( $c_p$ ), and settling velocity from this project are being combined with those from the another ONR funded project designed to explore methods for estimating particle density without collection of water samples. The efforts described here are now being extended to RIVET 2 in the mouth of the Columbia River. The two LISSTs used in this project were purchased with Canadian funds, one from a project on oil-mineral aggregation (NSERC, Hill) and one on particle transport away from finfish aquaculture sites (DFO, Law).

## IMPACT/APPLICATIONS

This proposal seeks to improve our ability to assess and predict the distribution of optical properties in the coastal region. Such information is needed to assess underwater visibility of relevance to both diving operations and underwater communication.

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### **HONORS/AWARDS/PRIZES**

Paul Hill, Award for Excellence in Teaching, Faculty of Science, Dalhousie University